Sacrificial Polymer use in the Creation of High Performance Circuit Boards

By: Spencer Temples
Mentor: Jisu (Aaron) Jiang
PI: Dr. Paul Kohl
Circuit boards in Electronics

Are an integral part of electronics

Needed for a base to print the electronics on

Provide support and structure
Capacitors and Dielectrics

Capacitors store charge in the electric field between two charged plates and dielectrics increase capacitance.

In microelectronics, the components of the circuit board act as the charged plates to parasitically store the charge.

\[ C = \frac{\varepsilon_0 k A}{d} \]

**TABLE 17-3 Dielectric constants (at 20°C)**

<table>
<thead>
<tr>
<th>Material</th>
<th>Dielectric constant (K)</th>
<th>Dielectric strength (V/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuum</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>Air (1 atm)</td>
<td>1.0006</td>
<td>$3 \times 10^6$</td>
</tr>
<tr>
<td>Paraffin</td>
<td>2.2</td>
<td>$10 \times 10^6$</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>2.6</td>
<td>$24 \times 10^6$</td>
</tr>
<tr>
<td>Vinyl (plastic)</td>
<td>2.4</td>
<td>$50 \times 10^6$</td>
</tr>
<tr>
<td>Paper</td>
<td>3.7</td>
<td>$15 \times 10^6$</td>
</tr>
<tr>
<td>Quartz</td>
<td>4.3</td>
<td>$8 \times 10^6$</td>
</tr>
<tr>
<td>Oil</td>
<td>4</td>
<td>$12 \times 10^6$</td>
</tr>
<tr>
<td>Glass, Pyrex</td>
<td>5</td>
<td>$14 \times 10^6$</td>
</tr>
<tr>
<td>Rubber, neoprene</td>
<td>6.7</td>
<td>$12 \times 10^6$</td>
</tr>
<tr>
<td>Porcelain</td>
<td>6–8</td>
<td>$5 \times 10^6$</td>
</tr>
<tr>
<td>Mica</td>
<td>7</td>
<td>$150 \times 10^6$</td>
</tr>
<tr>
<td>Water (liquid)</td>
<td>80</td>
<td>$8 \times 10^6$</td>
</tr>
<tr>
<td>Strontium titanate</td>
<td>300</td>
<td></td>
</tr>
</tbody>
</table>
Epoxy Resins in Circuit Boards

Common in industry for printed circuit boards

Cheap, easy to make, and strong

Bisphenol A diglycidyl ether (BPADGE)
Our Plan
To make a low dielectric material by creating a nano porous epoxy resin (to maximize air in the film)

Pumice stone ➔
(A strong porous material)
Overview

Poly-Propylene Carbonate (PPC)

Porogen
Multiple chain lengths
\( n=20 \)
\( n=10 \)
Shorter chain lengths reduce steric hindrance

Styrene Maleic Anhydride (SMA)

Multiple Styrene to Maleic Anhydride ratios used:
4:1
2:1
Ratio controls how much porogen can be incorporated

Maleic Anhydride is the bonding site, so increasing this ratio (2:1) allows more incorporation of ePPC
Why PPC?

Propylene Carbonate (Volatile)
Evaporates to create pores

Crosslinking agent that improves mechanical properties of epoxy resin
Acts as grafting site for PPC and locks porogen in place before phase segregation can occur

Why SMA?
Reaction Mechanism

The PPC is functionalized and then grafted onto an SMA chain.
Why the Grafting Instead of Just Mixing

To spread out the pores evenly and prevent phase segregation (clumping)

This preserves mechanical properties

← Not This large Pores as a result of clumping

↓ Evenly spread pores

This→
Process

Mixture precipitated in Hexane

Mixed with BPADGE

Spin coated onto wafer
Process (continued)

Samples cured on hot plate (activates porogen)

Made into capacitors with e-beam evaporator (deposits Al)

Capacitance is measured
The Capacitor (Parallel Plate)

Parallel plate capacitor

Shadow mask for Al deposition

Al

Polymer Film

1.05 μm

Si
Objective

Studying the effects that increasing amounts of pores have on the dielectric constant and glass transition temperature of the material
Glass Transition Temperature

The temperature that epoxy resin transition from a hard, glassy substance to a soft, rubbery substance

$\text{DSC}$ (Differential Scanning Calorimeter) used to measure the Tg
Glass transition temperature decreases with increasing number of pores caused by a decrease crosslink density.
Index of Refraction

This Index is closely linked to the relative permeability of the object (indicates the dielectric constant of the substance)

\[ n = \frac{c_{\text{vacuum}}}{c_{\text{lens}}} = \frac{\text{velocity of light in vacuum}}{\text{velocity of light in lens}} \]
Index of Refraction with Various Percentages of ePPC

Wave length of Light [nm]
Dielectric Constant of Various Weight Fractions of ePPC

Lines show trend with linear progression.
Future Works

Investigate distribution and integrity of the pores

Image nanoporous structure and determine the distribution of pore size

Measure mechanical properties to determine the effect of increasing porosity

Increase grafting ratio beyond 40% ePPC

Mix with free SMA to increase cross linking sites for improved Tg
Acknowledgments

Kohl Group
IEN
SENIC
Leslie O’Neil
Dr. Nancy Healy
Clean room staff